DOCUMENT RESUME

ED 054 651 EM 009 251

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TITLE Computer Terminal Selection: Some Instructional and Psychological Implications.

INSTITUTION Florida State Univ., Tallahassee. Computer-Assisted Instruction Center.

SPONS AGENCY Office of Naval Research, Washington, D.C. Personnel and Training Branch.

PUB DATE 15 May 71

NOTE 29p.

EDRS PRICE MF-$0.65 HC-$3.29

DESCRIPTORS Anxiety; *Computer Assisted Instruction; *Cost Effectiveness; *Input Output Devices; *Intermode Differences; Low Ability Students

ABSTRACT

Factors which have previously provided the basis for decisions as to the use of CRT (cathode ray tube) of teletype terminals in computer-assisted instruction (CAI) may be decreasing in importance. Specifically, differential cost factors and teleprocessing capability may no longer provide a basis for differentiating between CRTs and teletypes. In this paper several experiments are reviewed, and the instructional and psychological implications of instructional terminals are discussed. The major terminal characteristics discussed are cost, teleprocessing capability, presentation, rate, and display mode. The major instructional and psychological implications discussed are device memory load factors and instructional time and efficiency. Student characteristics of intelligence and anxiety are discussed in relation to instructional terminal characteristics. (Author)

ED054651

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TECH MEMO

COMPUTER TERMINAL SELECTION: SOME INSTRUCTIONAL AND PSYCHOLOGICAL IMPLICATIONS

Bobby R. Brown and Harold F. O'Neil

Tech Memo No. 37
May 15, 1971

Project NR 154-280
Sponsored by
Personnel & Training Research Programs
Psychological Sciences Division
Office of Naval Research
Arlington, Virginia
Contract No. N00014-68-A-0494

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Duncan N. Hansen
Director
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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Florida State University
Computer-Assisted Instruction Center
Tallahassee, Florida

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

COMPUTER TERMINAL SELECTION: SOME INSTRUCTIONAL AND PSYCHOLOGICAL IMPLICATIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Memo No. 37, May 15, 1971

5. AUTHOR(S) (First name, middle initial, last name)

Bobby R. Brown and Harold F. O'Neil, Jr.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 15, 1971	16	11

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
N00014-68-A-0494	
b. PROJECT NO. NR 154-280	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
c.	
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Personnel & Training Research Programs Office Of Naval Research Arlington, Virginia

13. ABSTRACT

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DD FORM 1473 (PAGE 1)
1 NOV 65
S/N 0101-807-6811

Security Classification
A-31408

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

FORM 1473 (BACK)
DD 1 NOV 65
S/N 0101-807-6821

Security Classification
A-31409

Student characteristics of intelligence and anxiety are discussed in relation to instructional terminal characteristics.

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ABSTRACT

Factors which have previously provided the basis for decisions as to the use of CRT or teletype terminals in computer-assisted instruction may be decreasing in importance. Specifically, differential cost factors and teleprocessing capability may no longer provide a basis for differentiating between CRTs and teletypes. In this paper, in which findings from several experiments have been reviewed, instructional and psychological implications of instructional terminals are discussed. The major terminal characteristics discussed are cost, teleprocessing capability, presentation rate, and display mode. The major instructional and psychological implications discussed are device memory load factors and instructional time and efficiency.

Student characteristics of intelligence and anxiety are discussed in relation to instructional terminal characteristics.

COMPUTER TERMINAL SELECTION: SOME INSTRUCTIONAL AND PSYCHOLOGICAL IMPLICATIONS

Bobby R. Brown and Harold F. O'Neil

During the past decade, within computer-assisted instruction (CAI), considerable attention has been given to the problem of "student-subject matter interface." Within CAI the student-subject matter interface refers to those devices which are employed for the presentation of stimuli to the student and for entering of student responses. Stimulus presentation is accomplished through devices such as cathode ray tubes (CRT), two-way typewriters or teletypes, slide projectors, tape recorders, etc. Student response capability is provided by typewriter keyboards, light pens in conjunction with CRT, and other special devices such as the "Rand Tablet" and touch sensitive keyboards.

Due primarily to cost factors and considerations growing out of computer technology, two of these interface devices have gained far more widespread use than the others. These are the CRT, with or without light pen capability, and the hard copy typewriter or teletype. Of these two devices, the hard copy typewriter or teletype is currently the predominant student-subject matter interface device in use with CAI.

The predominance of teletype terminals is due mainly to cost factors. The usual price for a CRT terminal being about twice that of a teletype. However, since the creation of inexpensive terminal equipment

is one of the dynamic areas in computer technology, one can anticipate a significant decrease in their cost. The price of CRT terminals is decreasing monthly and some projections indicate the CRT may become as cheap as a color TV set in the future.

An additional factor growing out of computer technology which has in the past favored teletype terminals over CRTs has to do with the capability of teleprocessing. In the past it has been impossible to teleprocess to many CRTs for distances in excess of approximately 2,000 feet due to a need to amplify the video signal. This factor has obviously severely limited the teleprocessing application of CRT terminals. However, with the advent of teletype compatible CRTs which do not require amplification of the video signal, teleprocessing distance is no longer a limiting factor.

Given reasonably comparable cost figures in the near future and equivalent teleprocessing capabilities in the present, on what basis does the administrator choose either teletype terminals or CRT terminals? There seem to be three primary differences which can be noted as a basis for decision making: First, the CRT terminal provides more rapid presentation of instructional materials. The typical teletype terminal presents instructional material at approximately 125 words per minute, or far below the average reading speed of high school and college students. In contrast, CRT terminals present material a screen at a time, or far in excess of the reading speed of even the faster readers. Second, the CRT does not provide the student with a hard copy of his interaction with the computer while the teletype does. A third difference to be noted between these two devices is the relative noise generated by each device. The CRT is

noticeably quieter in operation than the teletype. With many teletypes operating simultaneously within a relatively small area, thenoise level could conceivably become a debilitating factor in instruction.

Given that past choices between teletypes or CRTs have been based primarily on cost consideration and factors growing out of computer technology, it is not surprising that few studies have investigated the instructional and psychological implications of terminal selection. However, with the decreasing importance of cost and teleprocessing considerations in the selection of terminals, it becomes increasingly important to consider the psychological and instructional implications of the type of terminal selected.

In the remainder of this paper we will focus upon the instructional and psychological implications of terminal selection, focusing primarily upon CRT versus teletype terminals. The findings which we will review offer the basis for some tentative conclusions concerning terminal selection as well as pointing up areas in need of further investigation.

Memory Load Characteristics

The lack of hard copy and the more rapid presentation rate of a CRT terminal yield an important but seldom mentioned difference between CRT and teletype presentations. Due to the more rapid and transitory nature of CRT presentations of material there is a potentially higher memory load for CRT presentations than for teletype presentations of the same instructional material. Suggestive evidence as to the importance of memory load has been provided by a series of studies conducted at the Florida State University Computer-Assisted Instruction Center. The impact of differential memory load of the teletype comped to the CRT seems to debilitate two groups of people seriously. One group consists

of students of below average intelligence, and the other group consists of the high anxious students.

Intelligence. Evidence for the negative impact of a CRT presentation for low I.Q. students was found by Dick and Latta (1969). They presented math materials via CRT and programmed instruction. The CAI program had the same basic frames as the PI texts plus remediation for incorrect responses as well as remedial loops. Results of the posttest, retention test, and "in program" errors indicated that the low ability students performed poorer than the high ability students and further that students receiving programmed instruction performed significantly better than those using CAI. In each case, these effects were due to the poor performance of the low ability students who used the CRT terminal. Dick and Latta (1969) suggested that the low ability students were unable to cope with the continuous flow of information as presented by the CRT without the ability to return to previously presented information. It can be further hypothesized that without the avilability of a hard copy, this was primarily due to a memory demand that was not present with a PI presentation of the same material.

Anxiety. The impact of anxiety and its relationship to terminal characteristics can be inferred from three studies concerning anxiety and performance in a CAI setting. However, before briefly outlining the results of these studies, a distinction must be made between two facets of anxiety. According to Spielberger (1966) state anxiety refers to a transitory state or condition that is characterized by feelings of tension and apprehension, and heightened autonomic systems activity. Trait anxiety implies an individual difference of anxiety proneness,

i.e., the disposition to respond with elevations in A-State under conditions characterized by some threat of self-esteen. O'Neil, Spielberger, and Hansen (1969) investigated the effects of A-State on performance for materials that were presented by a 1440 CAI system (IBM, 1965). In this study, the State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970) was used to measure state anxiety during the learning task. They found that high A-State students made more errors in the difficult portion of the learning task than low A-State students and did as well as the low A-State students in the easier portions of the task. In the follow-up study, O'Neil, Hansen, Spielberger (1969) found essentially the same A-State by task difficulty interaction. However, in the second study the mean error rate of the high A-State students on the difficult portion of the CAI task was approximately twice that of the first study.

One of the major differences between these two studies was that the learning materials in the first study were presented on a typewriter terminal and in the second on a CRT terminal. The typewriter terminals provided a printed output of the learning materials and the student's responses, thus the student could review his previous erroneous responses prior to each trial. In contrast, the materials presented on the CRT were programmed to be erased immediately after the subject responded. Thus, there may have been a greater memory load for the CRT. This may have accounted for higher mean error rates for high A-State students for the second CAI study. The typewriter printout seems to have provided greater memory support in the first CAI study.

Leherissey, O'Neil and Hansen (1970) argued that one method for reducing errors of the high A-State students for learning materials presented on the CRT would be to provide some type of memory support. They predicted, therefore, that there would be no differences between the high and low A-State students with memory support and that the performance of high A-State students would be inferior to that of the low A-State students without memory support. The memory support consisted of allowing the students to see the previous incorrect responses to each problem before attempting it again, whereas this information was not available to the no-memory support group. The no-memory support group was equivalent to the groups run in the O'Neil, Hansen and Spielberger (1969) study on typewriter terminals. Leherissey et al. (1970) found, as predicted, that memory support reduced the errors by high A-State students; i.e., high A-State students in the memory support condition made approximately 1.75 fewer errors than high A-State students in the NMS condition, lower medium A-State students performed equally as well with or without memory support.

Of major interest for this paper was the finding (Leherissey et al. 1970) that the provision of memory support reduced the errors of the high A-State male students on CRT terminals to a rate of errors equivalent to that of the high A-State students on typewriter terminals. Although performance improved in the memory support condition of Leherissey et al., the level of A-State was found to be higher for students in the memory support group as contrasted to the no-memory support group. This difference approached significance ($p < .10$). They inferred that the memory support condition could be operating as a stress condition in

that providing students with their previous incorrect responses was also providing them with a constant reminder of their past failures.

It would appear on the basis of the three studies of anxiety and computer-assisted learning that memory support was successful in reducing male students' errors. However, Leherissey et al. further suggest that such a benefit may produce within the student an undesirable side effect of state anxiety. Thus, it would seem to be desirable to design memory aids which not only reduce the memory load of the CRT, but which also reduce the anxiety experienced in a learning situation.

Additional evidence concerning the differential memory load characteristics of presentation devices is provided by an experiment in which subjects were presented material via three presentation devices (Brown, Hansen, Thomas, & King, 1970). In addition to teletype and CRT presentations, students were also presented instructional material via audiotape. In addition to generally confirming the findings of the studies above, the findings from this experiment provide suggestive evidence concerning two additional factors relating to device memory load characteristics. Thus the findings will be presented in some detail. The first characteristic concern is the ability of students to perceive the memory load characteristics of terminal devices; the second offers some indication as to the possibility of offsetting undesirable effects of memory overload through increased redundancy of instructional materials.

In the portion of the Brown et al. (1970) experiment which is of interest in this paper, subjects were allowed to select jointly the presentation device and the redundancy level of the instructional material to be presented. The instructional device choices given to the subject

were those listed above, namely CRT, teletype and audiotape. The redundancy levels of the instructional material available for subject selection were terse, medium and redundant.

The first portion of the course was administered in such a way as to introduce the students to the three presentation devices and the three levels of information load or redundance. The subjects were then required to choose the presentation device and redundance level for their next segment or instruction. Following the selection, the segment of the instruction was presented via the selected media and at the selected redundance level. This decision process occurred a total of three times for each student as the student progressed in the course.

The decisions made by the students in their three choices of media device and redundancy level are presented in Table 1. Table 1 also shows the proportion of choices of each information level for a given choice of device. A χ^2 calculated for the choice frequencies indicates the presence of nonchance factors in the pattern of choices (observed χ^2 = 59.45, df = 8, $p < .001$).

As can be seen from Table 1, learners who chose audiotape presentation chose 50% of those presentations at the redundant level while students who chose typewriter presentations chose 59% of those presentations at the terse level. The selection of predominantlt redundant presentations from the device which has high memory load characteristics coupled with the choice of terse material from the device which has low memory load characteristics seems to indicate that subjects were optimizing their device-redundancy level choices in such a way as to make the memory load manageable. These findings seem to suggest subject awareness of memory load device characteristics and the possibility of offsetting

TABLE 1

The Frequency and Proportion of Choices of Device Redundancy Level Combinations for Three Choices by Learner Control Subjects

	Redundancy Level			
	Terse	Medium	Redundant	Total
Device:				
Audio Tape	2 (.25)*	2 (.25)	4 (.50)	8 (1.0)
CRT	28 (.45)	17 (.29)	14 (.24)	59 (1.0)
Typewriter	19 (.59)	8 (.25)	5 (.16)	32 (1.0)
Total	49	27	23	99

*Proportion of choices is given for each redundancy level for a given choice of device.

unmanageable memory loads by increasing the instructional redundancy level.

Time and Instructional Efficiency

In the studies reviewed above one could conclude that the teletype terminal should be perferred over the CRT due to its lower memory load requirements. However, this finding must be carefully weighed against the consistently observed finding that teletype presentation requires significantly more instructional time than does CRT presentation. These differential time requirements also have implications for instructional system usage, scheduling constraints, and possible student motivation effects.

Evidence as to the differential time requirements of teletype and CRT terminals was found by Brown, Hannum and Dick (1971). Twenty-eight students taking a credit-earning graduate level course in programmed instruction via computer managed instruction (CMI) were randomly assigned to CRT and teletype terminals. The mean time to complete 12 instructional units of this CMI program for the CRT students was 261 minutes, the mean time for the teletype students was 354 minutes, indicating that the CRT group spent significantly less time signed on to the computer during this study ($p < .02$).

As a part of the course requirement in this study, each student developed and carefully documented a short unit of programmed instruction materials. It is of interest to note that based on the independent judgment of three evaluators, the CRT group scored significantly higher on this class project. This finding points up the importance of differential instructional time requirements. Analysis of the rate of progress

through the course for the two groups revealed that the CRT group not only took significantly less time, but individual students within the CRT group tended to complete more units within the course each time they signed on to the system. Thus, they were able to complete the instructional portion of the course sooner than the teletype group, allowing additional time to be spent on the development and documentation of their programmed instruction unit. This interpretation, if correct, suggests that instructional time requirements may have implications beyond those observed by simple mean comparisons of total time by allowing fewer scheduled periods on the instructional system. The lower time requirements of the CRT seemed to have had scheduling effects resulting in the saving, not of minutes, but of days.

Analysis of the on-line error rate for the two groups did not reveal significant differences; however, the teletype group did make fewer errors than the CRT group. It is of interest to note that this investigation, in which no significant differences in program errors attributable to memory load factors were observed, differed from the above studies on one rather crucial dimension. In the previously mentioned studies, the instructional materials were presented to the students at the instructional terminal. In this CMI study, however, learning materials were presented off-line and only the questions and diagnostic statements were given to the students on-line. The failure to observe memory load differences between the two presentation devices is seen as an indication that the application demand characteristics of CMI may be so minimal as to render memory load differences inconsequential.

The relative inefficiency of hard copy typewriter terminal devices has been observed by others as well. Wodtke and Gillman (1966) observed an increase of approximately 1/3 in time required to complete instructional material when that material was presented by a hard copy typewriter rather than an off-line programmed text. This differential was further increased for students with minimal typing skills.

It would seem that the desirable feature of supplying the student with memory support through the provision of a hard copy is to be purchased at the expense of less efficient use of student time. Conversely, the speed and efficiency with which instructional material can be presented via CRT may be purchased at the expense of an unmanageably heavy memory load requirement.

Additional considerations which should be borne in mind in choosing between CRT terminals and teletype terminals have previously been alluded to, and include such factors as the relative operational noise level of the various devices. If terminals are to operate within a classroom where other non-terminal oriented instructional activity may also be taking place, the noise level of teletype terminals could become objectionable. Also, there are certain situations in which the absence of hard copy as provided by teletype terminals is a desirable feature of the CRT terminals. For example, the sequential dependency among test items becomes far less a matter of concern with CRT presentations. The student receiving test items on a CRT terminal does not have the opportunity to refer to earlier questions in answering any given questions. In many cases, this is a highly desirable feature and permits the presentation of questions which might be partially answered by preceding

questions. Should the student have access to a hard copy of such a test, the ability to refer to prior questions would tend to invalidate such a test.

One additional psychological factor should be briefly mentioned. It would seem that students have become inculturated, perhaps through traditional instruction, to expect and desire something to take with them upon leaving the instructional event. In traditional instruction this is typically the students' notes and perhaps other handouts supplied by the instructor. In CAI, this inculturated student expectation is apparently well met by the hard copy typewriter. When given the opportunity, students invariably take the hard copy of their instructional interaction with them. Upon numerous occasions it has been observed that students receiving instruction via CRT terminals feel ill at ease and express a desire to have notes or something to take with them upon leaving the instructional situation.

Tentative Conclusions

Factors which have previously provided the basis for decisions as to the use of CRT or teletype terminals may be decreasing in importance. Specifically, differential cost factors and teleprocessing capability may no longer provide a basis for differentiating between CRTs and teletypes. The advent of relatively inexpensive teletype compatible CRTs which also permit remote teleprocessing makes more salient the instructional and psychological bases for choosing between CRTs and teletype terminals.

There is evidence that the rapid and transitory display capabilities of CRT terminals may give rise to unmanageable memory load

requirements on students receiving instruction. These memory load requirements seem to be largely alleviated by the presence of a hard copy printout provided by teletypes.

Memory load considerations seem to be more important for highly anxious students and for students of below average intelligence. Reduction of memory load by the provision of memory support information may in some cases increase student anxiety.

Teletype terminals present instructional material at a rate considerably slower than the reading rate of high school or college students. It seems that this additional time requirement for teletype based instruction may have implications for scheduling and course completion in access of the simple additional on-line time required for instruction.

There are indications that the memory load requirements incurred with the use of CRT terminals can be overcome by tailoring the redundancy levels of the instructional material to the presentation device. Also, periodic review procedures along with instructional handouts may very well alleviate the high memory load requirements of the CRT presentations without incurring the additional time requirements associated with teletype presentations.

The operational noise level of teletypes, often a minor factor, can, in some situations, become a determining factor in selection of instructional devices.

The apparent desire on the part of most students to have some hard copy material to take with them upon leaving the instructional situation should be taken into account and some provisions made for this perceived need when employing CRT terminals.

The overall consideration of the student-subject matter interface seems to be grossly underinvestigated at this point. Full blown studies considering not only CRT and teletype terminals, but the full array of student-subject matter interface devices seems to be called for. Studies employing procedures such as those suggested by Briggs (1970) taking into account subject matter characteristics, learner characteristics, characteristics of the instructional process, and the specific instructional objectives, should greatly extend our understanding of student-subject matter interface requirements.

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